

# Electron Cloud Measurements at Fermilab

*Bob Zwaska*  
Fermilab

Project X Collaboration Meeting  
November 21, 2008

# Introduction

- Measurements made at Main Injector in present operation
  - Pressure Rises
  - Direct electron flux with RFA
    - Thresholds and conditioning
  - Microwave transmission
    - Distributed measurement
- Planned new measurements
  - New RFAs
    - Test at Cornell
  - Comparison of TiN coating
  - ECLLOUDx experiments

# Contributors

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Kathy Harkay, Richard Rosenberg – *ANL*

Bob Kirby, Mauro Pivi – *SLAC*

Mark Palmer – *Cornell LEPP*

Pardis Niknejadi – *UCLA*

Fritz Caspers – *CERN*



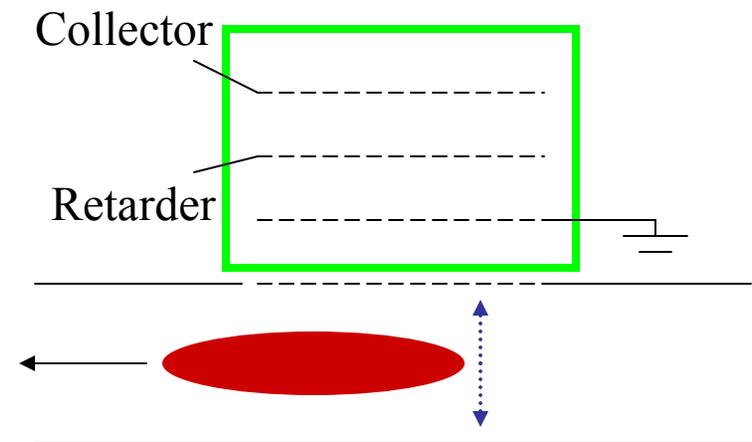


# Electron Probe

- Retarding Field Analyzer
  - Borrowed from Argonne
  - Installed in drift region
- Being used as an electron counter



- Not biasing retarder
- Output current is amplified and recorded
- Suffers from interference



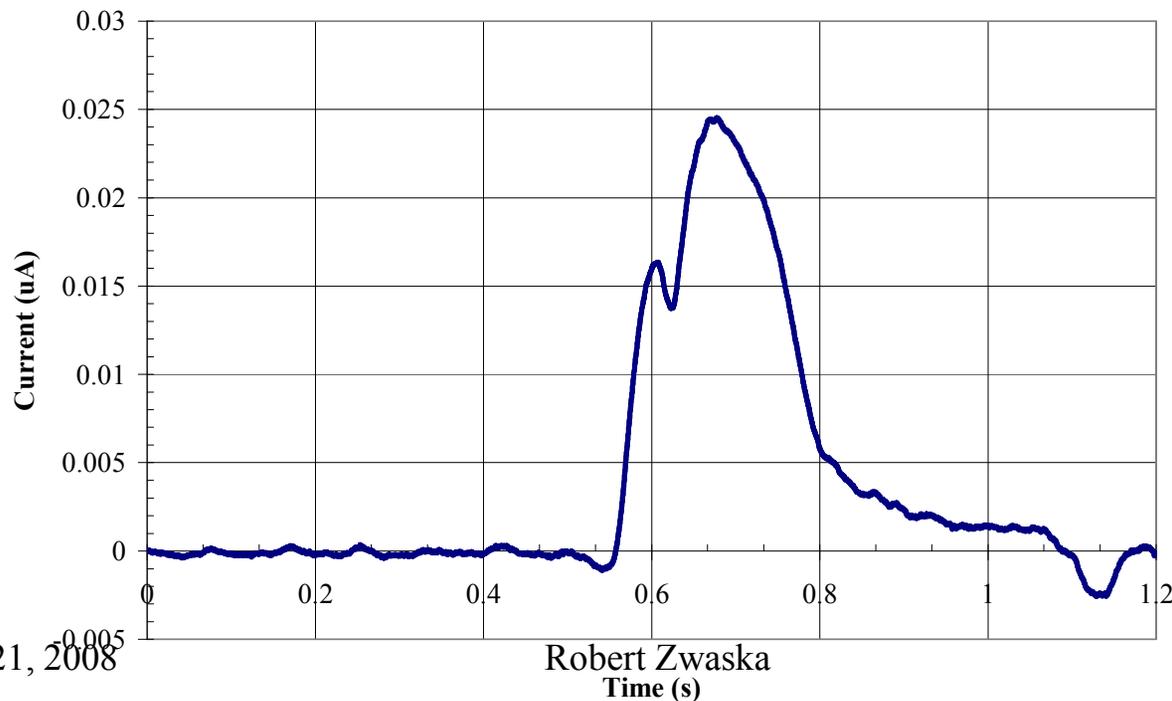
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➤ Measurement (continued)

# Single Cycle Measurement

- DC signal seen to spike at middle of cycle
  - Starts when beam is being accelerates
- Rapid increase of signal occurs into acceleration
  - Dip occurs at transition
  - Maximum occurs shortly after transition
  - Electron count decreases toward the end of the cycle
    - Not understood – try to check with new instrumentation

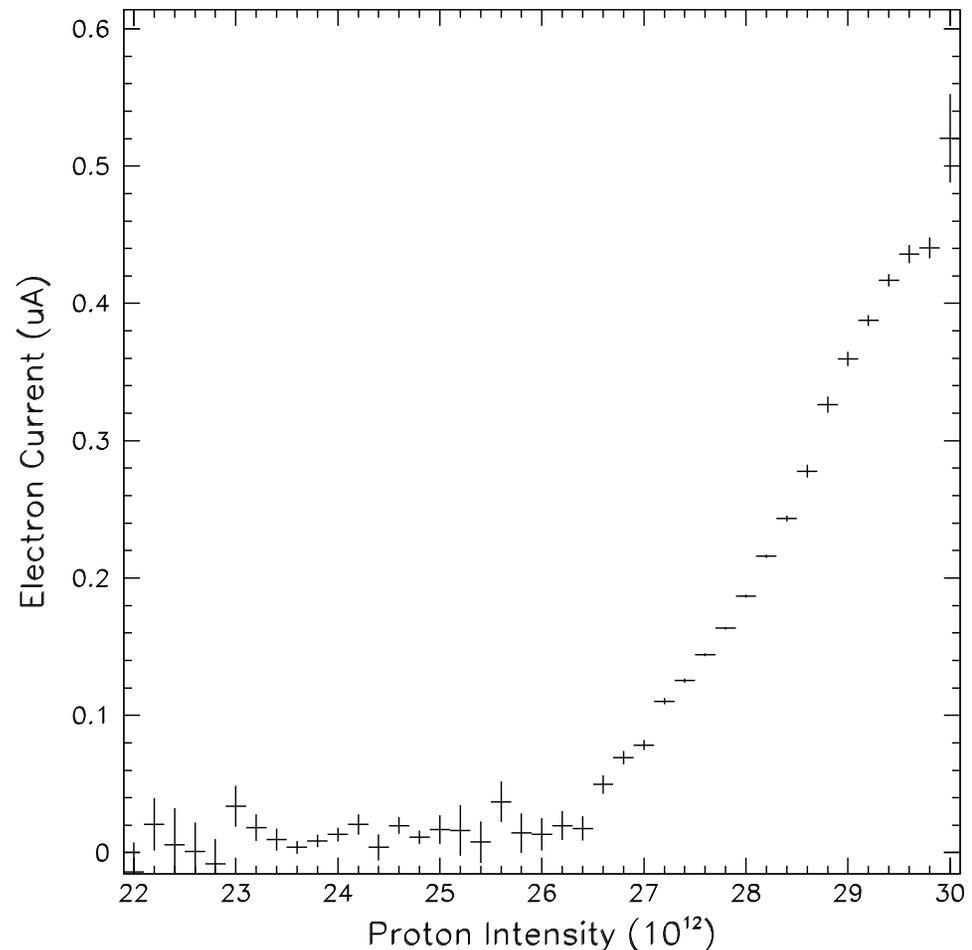


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Time (s)

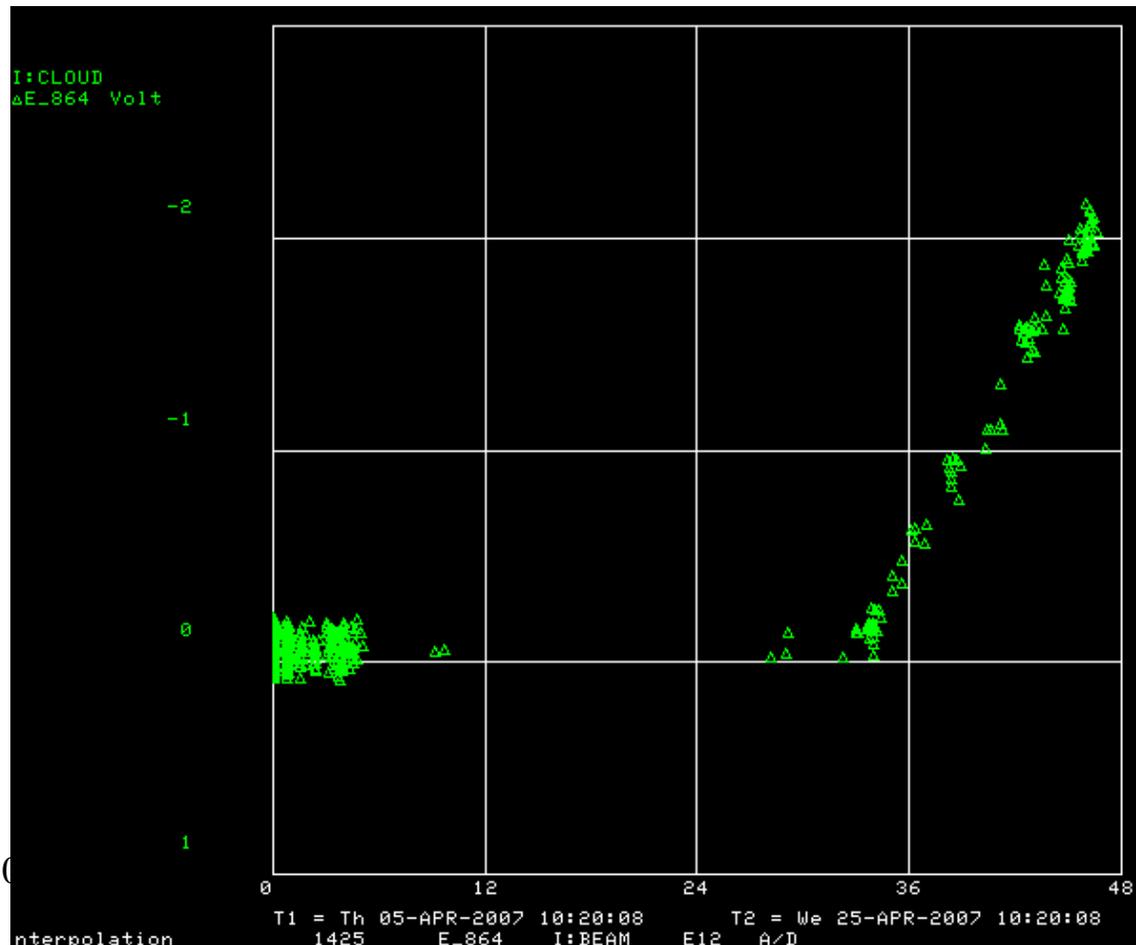
# Collected results

- Large number of cycles sampled at maximum current
  - Machine typically cycles every 2.2 s
- Clear turn-on at higher intensities
  - Threshold at  $\sim 26 \times 10^{12}$  (in this case)
- Noise due to amplifier/MADC system
- $0.2 \text{ uA} \sim 1\%$  neutralization



# High-Intensity Operation

- Highest MI operation at  $\sim 47e12$ 
  - ECloud current up to 2 uA
  - Threshold at  $33e12$



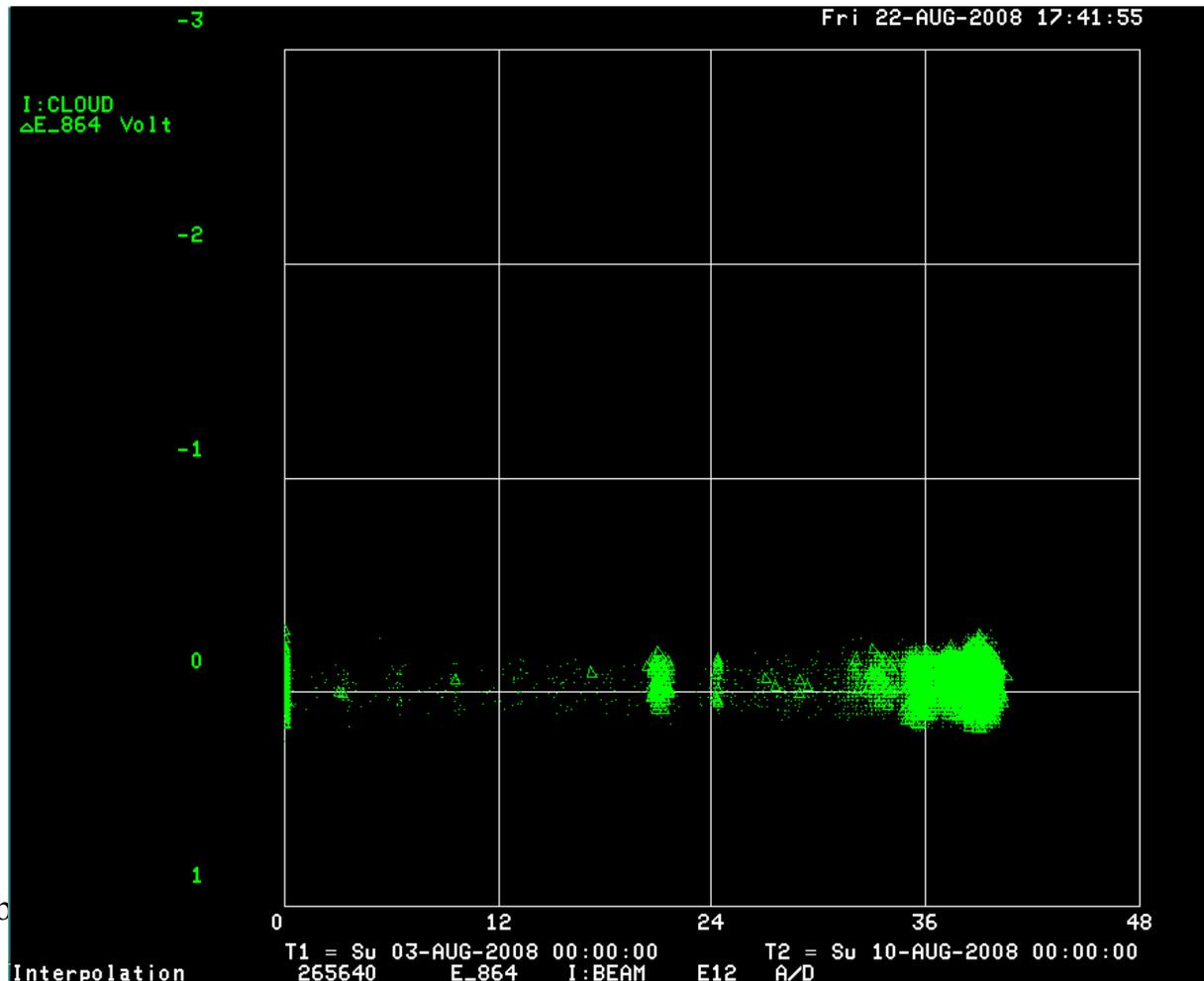
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# 2006-2007 Run Summary

- Threshold quickly rose to and stayed constant at  $34e12$
- High-intensity running was limited to studies
- Above threshold, RFA current increased at  $\sim 0.15 \text{ uA}$  per  $1e12$ 
  - Corresponds roughly to several % neutralization
- No instability observed in conjunction with ECloud
  - However, a small instability would not be noticed because of broadband damping performed for RW instability

# Recent Operation

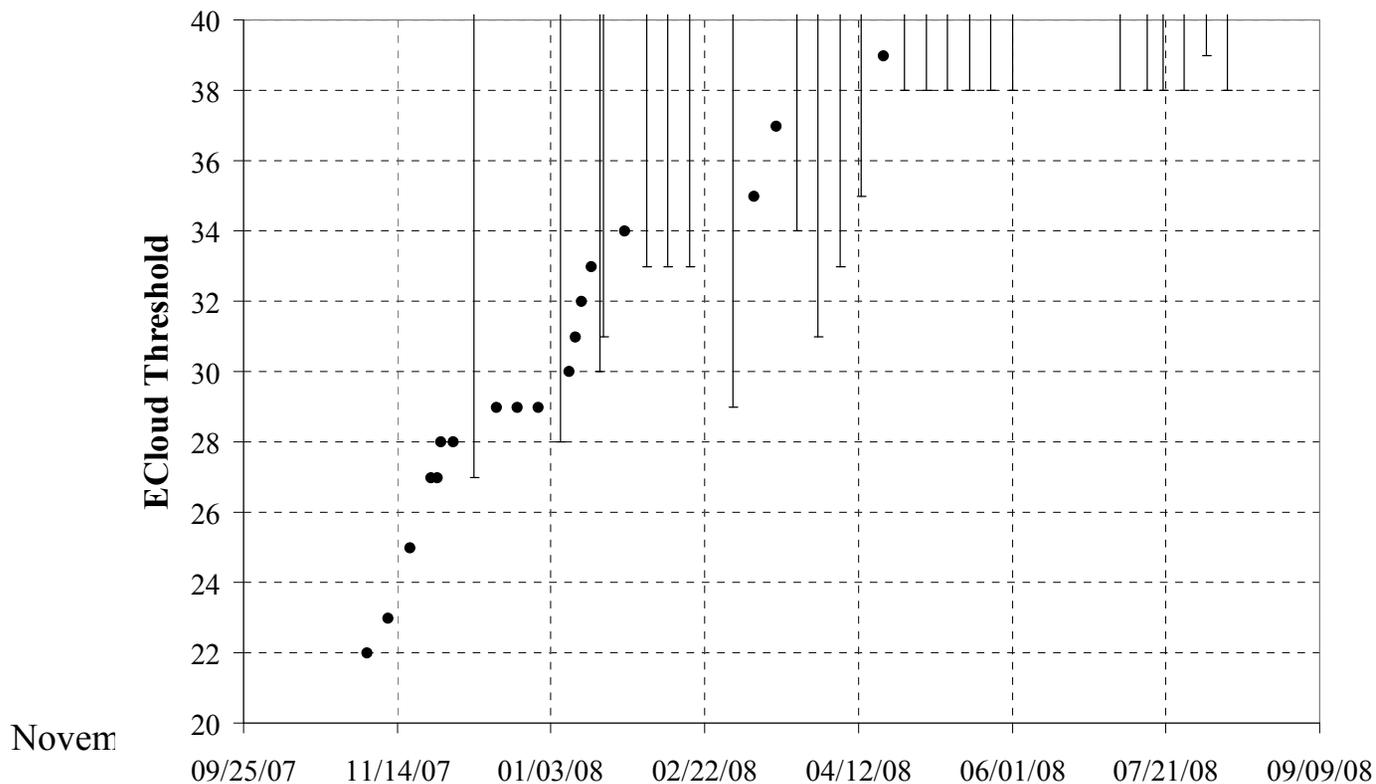
- Cloud signal is not above noise floor
- MI has not revisited its record intensities
- If MI gets back to  $>46e12$ , I expect a threshold at  $\sim 42e12$



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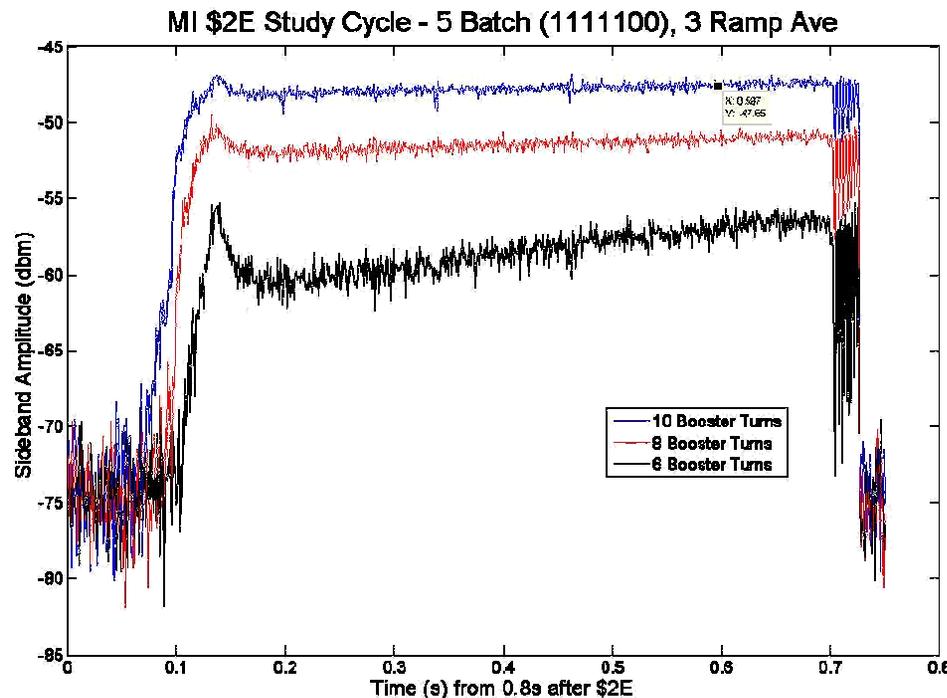
# 2007-2008 Run Summary - Conditioning

- Threshold started low and moved up to  $\sim 30e12$  with beam studies (Nov 07)
- When 11 batch became operational (Jan 08), threshold increased quickly
- 11 batch intensity increased in March 08, increasing threshold
- Threshold is now beyond the range of normal MI operation  $\sim 42e12$ 
  - Conditioning of beam pipe surface has reduced SEY
  - MI should be able to return to  $\sim 48e12$  sometime this run
  - Expect to see the ECloud reappear



# Microwave Transmission Measurements

- Using the procedure of Byrd, de Santis, *et al.*
- Broadcast 1.5 GHz microwave through BPM
  - Received at an adjacent BPM
  - Crosses 1 quadrupole & 2 dipoles in ~ 13m
- Phase modulation produces a strong sideband
  - Intensity expected to be roughly proportional cloud density
- Preliminary results suggest a strong cloud density
  - Still studying normalization, interference, and other detector affects
- Different behavior than RFA in straight section
  - Instrumentation? dynamics in magnets?



*N. Eddy, J. Crisp*

# Plans for PrX

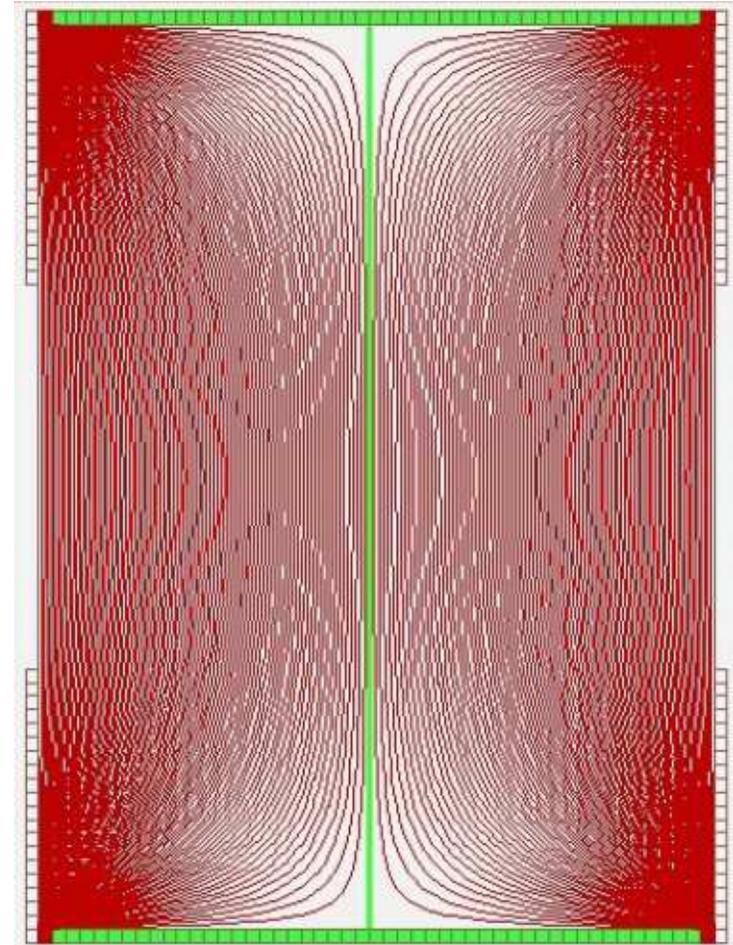
- Encouraging signs of conditioning of the MI's stainless
  - However, it is difficult to be confident to a tripling in intensity
- Considering coating all of the MI & RR's lengths with TiN
  - Beam pipes are captured in dipoles
  - Some *in situ* method needs to be developed
- R&D work (measurements):
  - New RFAs being developed
  - Tests of mitigation methods
  - Better & more measurements in the Main Injector to inform simulations
  - Standalone microwave measurement device

# New ECloud Detector

*C.Y. Tan*

- Designing new RFAs
- Need to clarify our observations in the MI
- Need several new detectors for teststands
  
- Design is based off of APS RFA
  - Optimizing energy filter behavior
  - Maximize signal collection
  - Reduce interference
  - Perform detailed calibration
  
- Will assemble prototype in next few weeks
- Final versions to be installed in MI next year
- Will also be used at CESR-TA

Simion Simulation



# Mitigation Methods

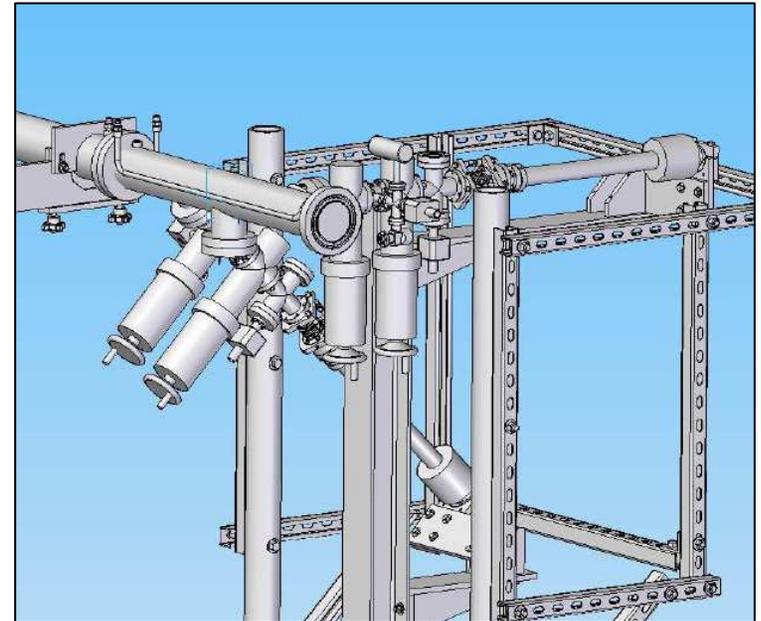
- Install a TiN coated section into MI straight in 2009
  - Compare to adjacent stainless section
  - Both instrumented with RFAs
  - Validate effect of TiN coating
- Test a clearing electrode at CESR in 2009
  - Low-impedance, zero aperture restriction design
  - Potentially also test in MI
  - However, this would be a difficult solution for PrX

# Further Measurements

- RFA experiments
  - Test with highest intensity and different fill patterns in MI
  - Install more RFAs
    - Potentially in magnets
- Microwave Propagation
  - Develop a standalone system
  - Measure in a region without dipoles, but still with quadrupole
  - Develop better antennas
    - Potentially measure in area without any magnets
- Other detection techniques
  - Optical, fiber, ...

# ELOUD<sub>x</sub>

- SLAC teststands for electron cloud experiments
  - Being installed at CESR-TA
  - Available for Fermilab in 2010
- ELOUD1
  - Measuring beam conditioning effects on surface materials
  - Allows removal of beam pipe surface “buttons” without breaking vacuum
  - Explicit measurement of SEY for different materials, with different beam exposures
- ELOUD3
  - 4 dipole chicane with RFAs and beam pipe material inserts
  - Allows testing of materials in arbitrary magnetic field



# Summary

- Measurements of electron cloud formation in MI
  - Vacuum pressure rise & Direct electron detection
    - Suggest few % neutralization
  - Threshold of formation is observed
    - Threshold increases over time – consistent with surface conditioning
  - Preliminary microwave measurements
    - Suggest strong neutralization in magnets
  - No instability observed in MI due to ECloud
    - Little guidance from simulation on whether there should be
- Several types of new instrumentation are under development
- Need to test coatings
  - Would like to test other mitigation methods
- Further measurements needed for simulation development
- Potential to reuse the existing SLAC equipment

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